Artificial Gravity:

Science Fact

Vs.

Science Fiction

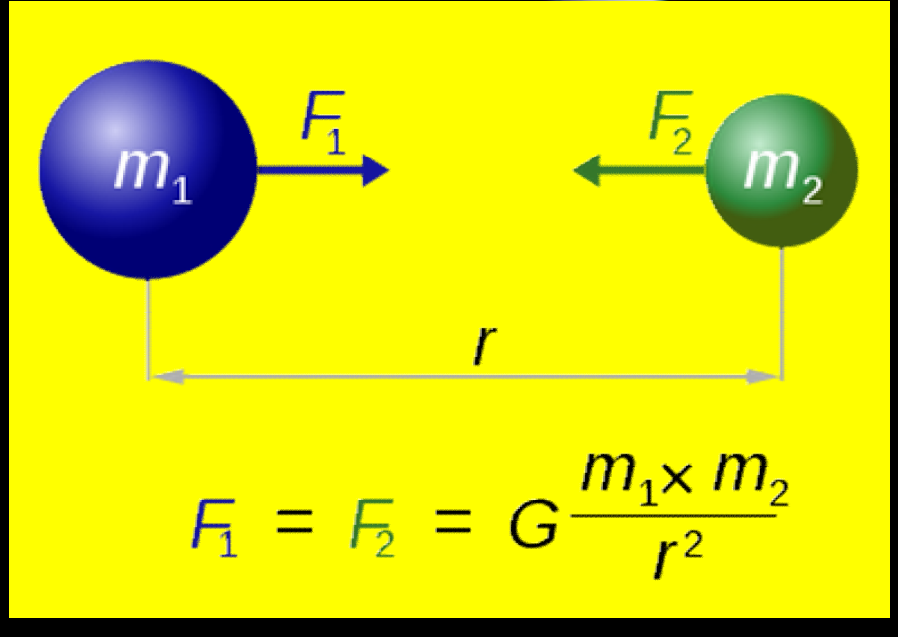
What is Gravity?

Gravity is the dominant force that is the cause of the formation, shape, and trajectory (orbit) of astronomical bodies like asteroids, comets, planets, stars, and galaxies.

It is responsible:

- **For causing the Earth and the other planets to orbit the Sun,**
- **For causing the Moon to orbit the Earth,**
- **For the formation of tides and natural convection,**
- **For heating the interiors of forming stars and planets to very high temperatures.**

Newton's Law of Universal Gravitation states that any two bodies in the universe attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.



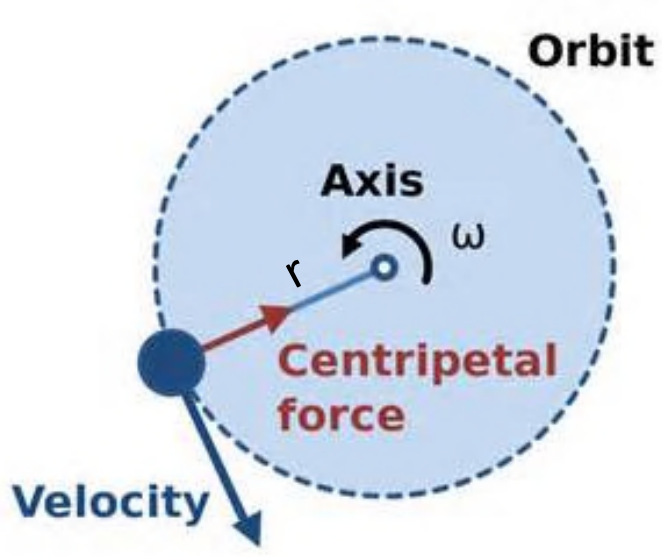
What is Artificial Gravity?

Artificial gravity is the theoretical increase or decrease of apparent gravity (g-force) by artificial means, particularly in space, but also on Earth. It can be practically achieved by the use of different forces, particularly centripetal force and linear acceleration.

A **centripetal force** (from Latin *centrum* "center" and *petere* "to seek") is a force that makes a body follow a curved path.

Angular velocity, ω, specifies the rotational speed of an object and the axis about which the object is rotating.

The SI unit of angular velocity is radians per second.



r = "radius", the distance to the center of rotation.

Newton's Third Law:

F = ma

(Force = mass x acceleration)

Centripetal force = $m\omega^2 r$

A circle has 2π radians.

Centripetal acceleration is $\omega^2 r$.

Centripetal Artificial Gravity as Depicted in Science Fiction

- 2001: A Space Odyssey – Rotating Space Station:

https://www.youtube.com/watch?v=4ll_6RimCuM

- 2001: A Space Odyssey – Centrifuge :

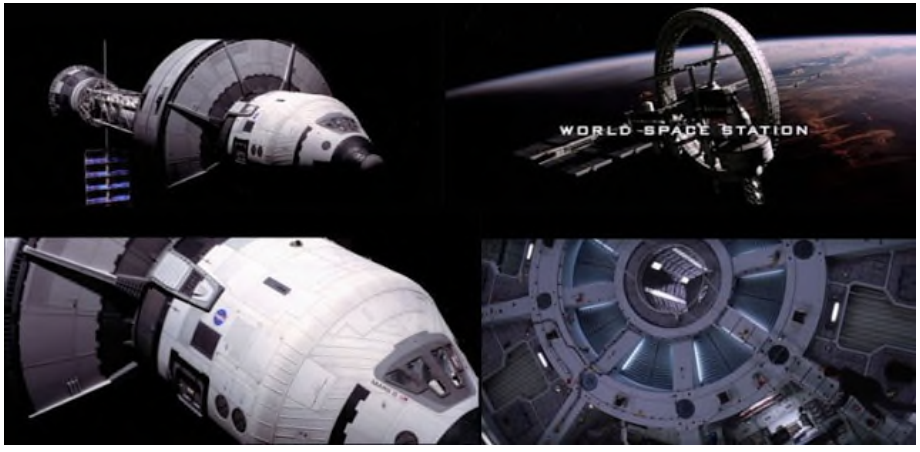
https://www.youtube.com/watch?v=1wJQ5UrAsIY

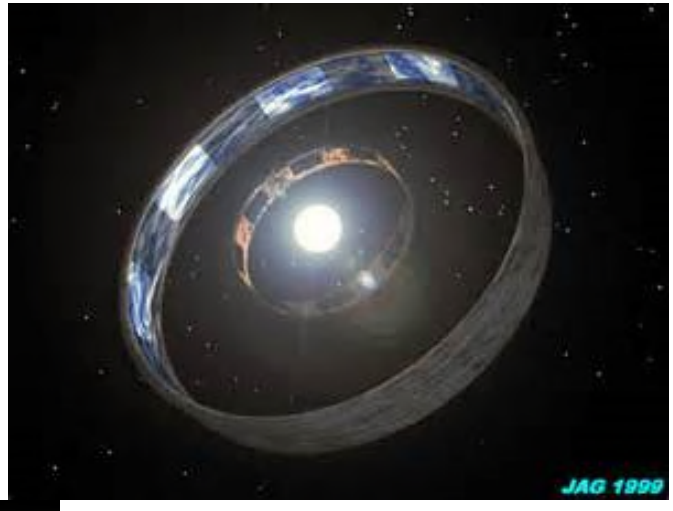
- 2010 – Rotate the habitable portion of the spacecraft (***Alexei Leonov***)

https://www.youtube.com/watch?feature=player_embedded&v=eCq9ntRK-QY

- Mission to Mars – Rotate an interior section of the spacecraft

http://www.metacafe.com/watch/6566713/mission_to_mars/



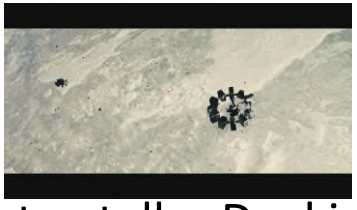


Ringworld

Elysium

Babylon 5

Halo



Interstellar Docking Scene

https://www.youtube.com/watch?v=7gkuBkea2Fc

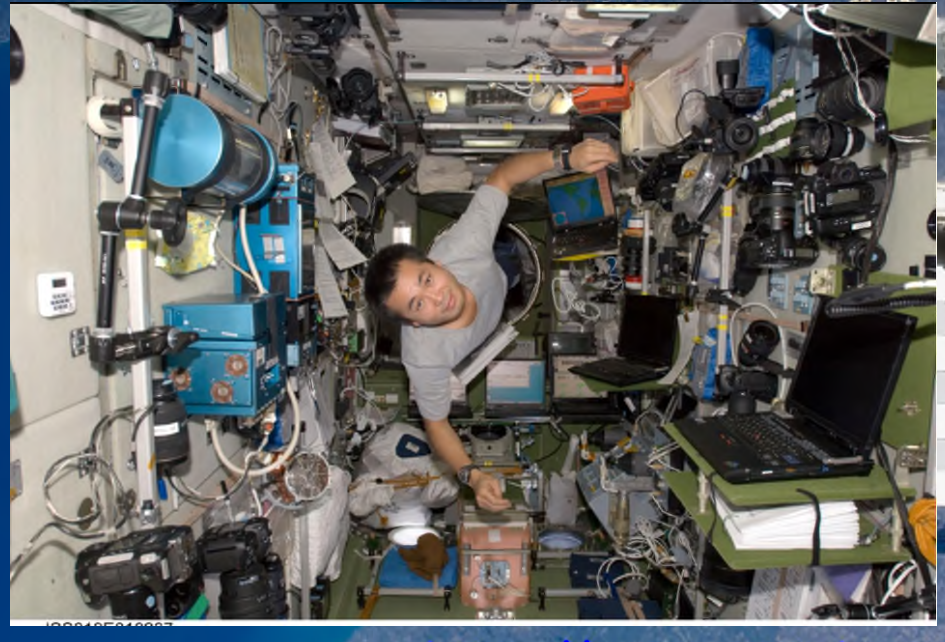
The ISS has been continuously inhabited since November 2, 2000

There is no Artificial Gravity on ISS. Astronauts live in *MICRO-GRAVITY (or free-fall)*

Earth's gravity attracts SS towards Earth, so the ISS is accelerated downward at almost 1g.

When viewed from an orbiting observer, other close objects in space appear to be floating because everything is being pulled towards Earth at the same speed and moving forward as the Earth's surface 'falls' away below.
All these objects are in free fall, not zero gravity.

And astronauts love living in micro-gravity!

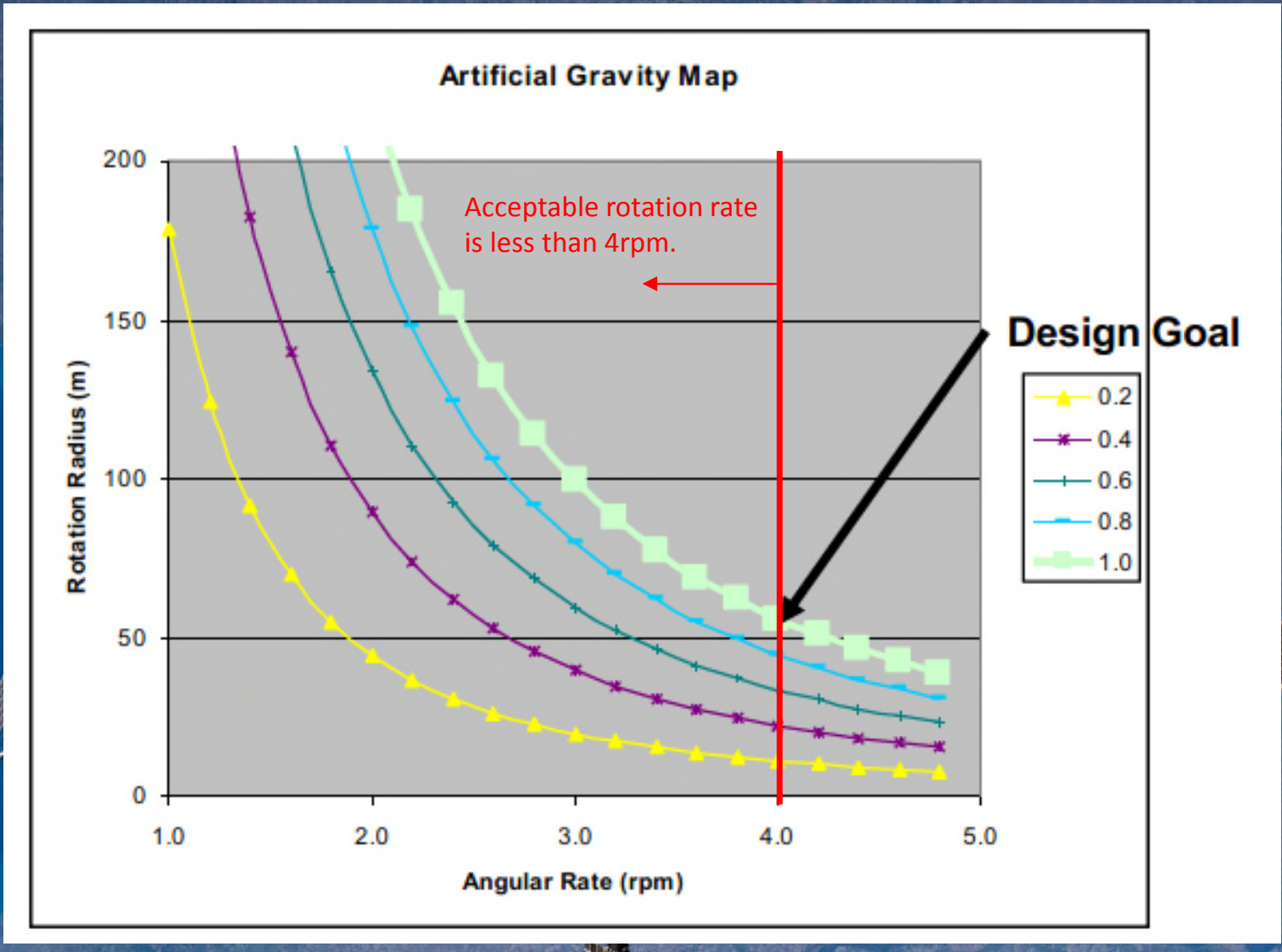


https://www.youtube.com/watch?v=YjZ6rydAT_Y

Musculoskeletal and Aerobic fitness has been maintained by ISS crew for 6-month missions.

Dysadaptation to microgravity includes visual impairment, orthostatic intolerance and loss of blood volume due to fluid shifts -- astronauts also have reported getting taller while on ISS!

How effective artificial gravity is in counteracting fluid shifts is not well understood



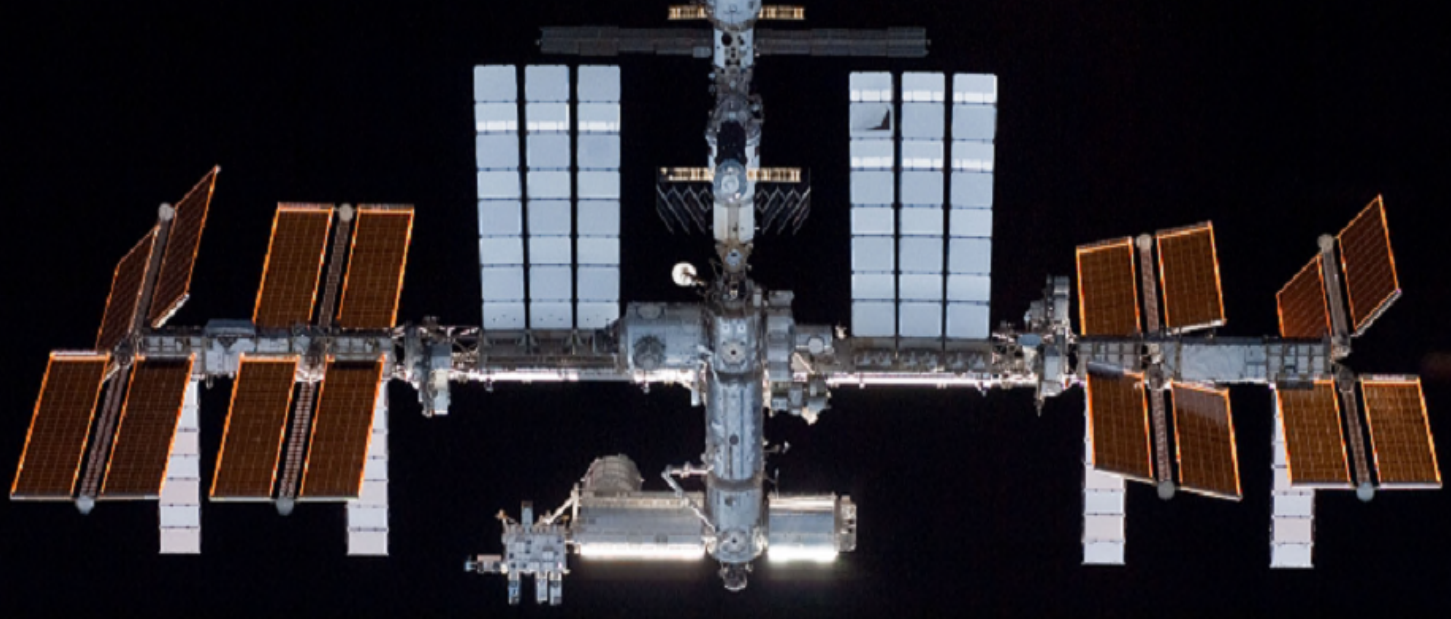
We need to understand the Gravity Dose Response Curve for the human body:

How high a gravity level and how long a duration is needed to provide astronaut health benefits?
(No data exists on "gravity doping" – exposure to levels higher than 1-g for periods of time)

Centripetal Artificial Gravity also exposes the crew to The Coriolis Effect

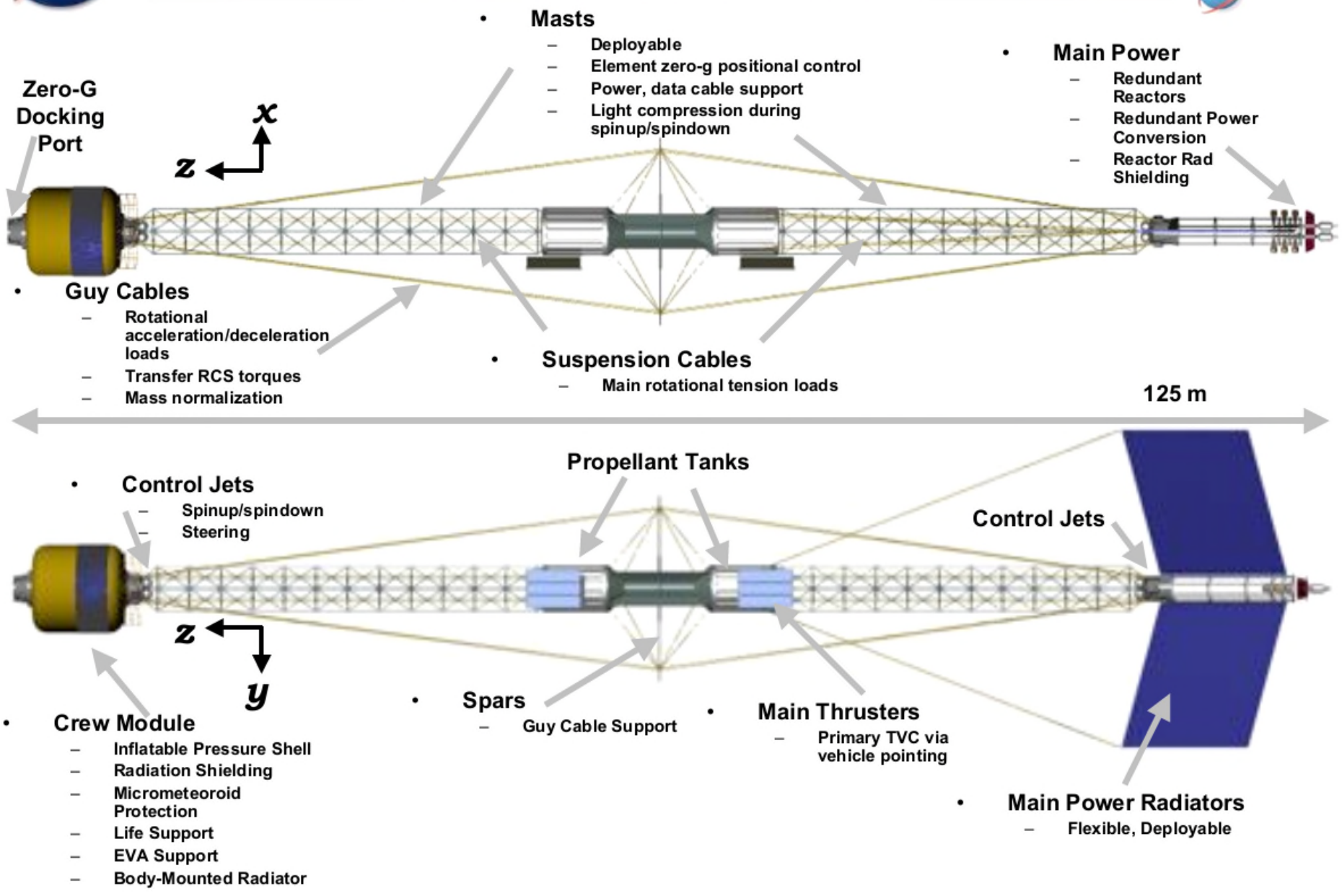
https://www.youtube.com/watch?v=dt_XJp77-mk

The Coriolis force acts in a direction perpendicular to the rotation axis and to the velocity of the body. It acts on the inner ear and can cause dizziness, nausea and disorientation. The nausea-inducing effects of Coriolis forces can also be mitigated by restraining movement of the head.

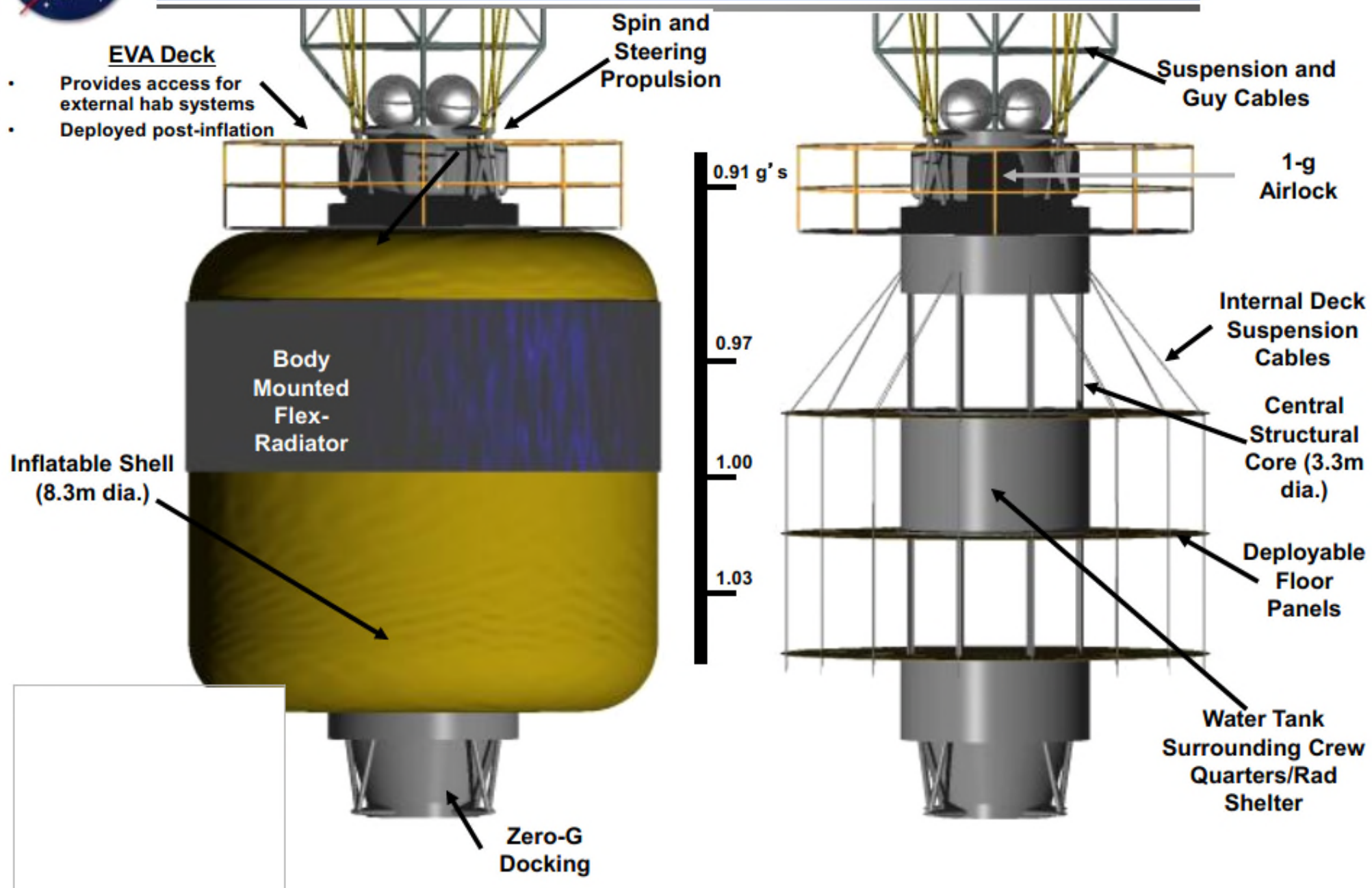


SO…What is NASA doing for artificial gravity?

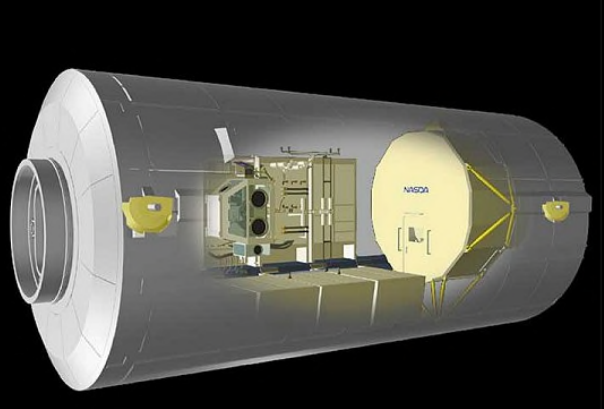
Current Configuration



Crew Module Concept



Short-radius centrifuge – a potential fluid shift countermeasure or means of gravity doping



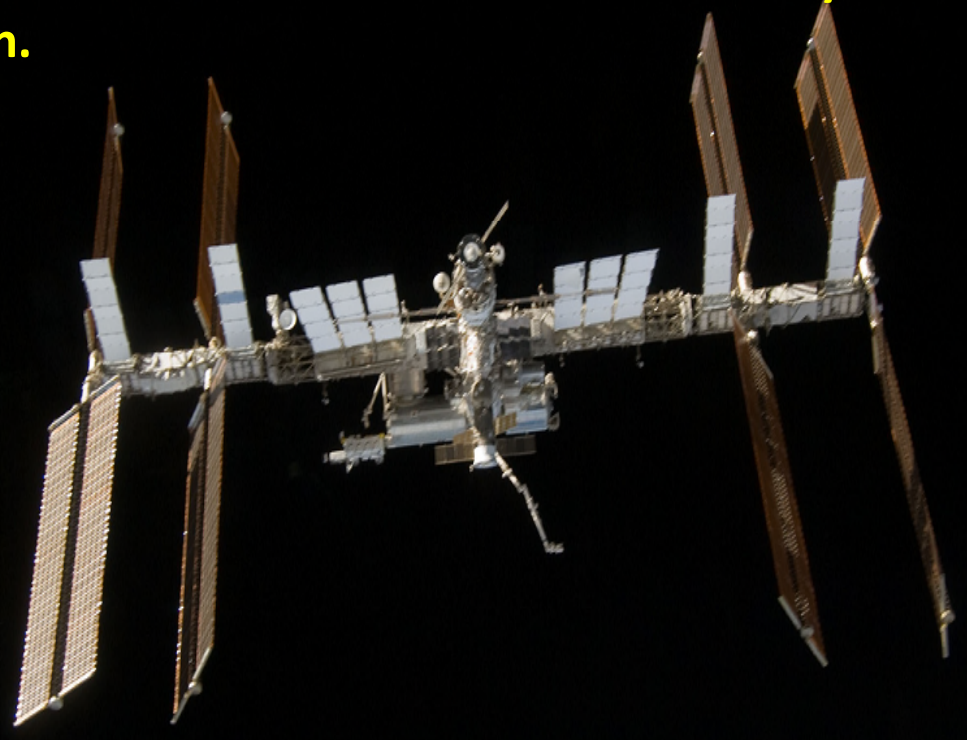
Small-scale centrifuges are in-use on ISS

- **ISS considered adding a centrifuge module for primate research.**

An enormous amount of work is needed to understand the benefits of artificial gravity for long duration human spaceflight.

Implementing centripetal artificial gravity on a spacecraft is feasible, but it will be complex, expensive and depending on the magnitude of the g-force and the exposure duration needed to provide health benefits, may result in a very large spacecraft.

Our current ISS mission durations do not cover the current 3-year duration needed for a round-trip Mars mission.



As our missions get more ambitious, the desire for artificial gravity may become a requirement.

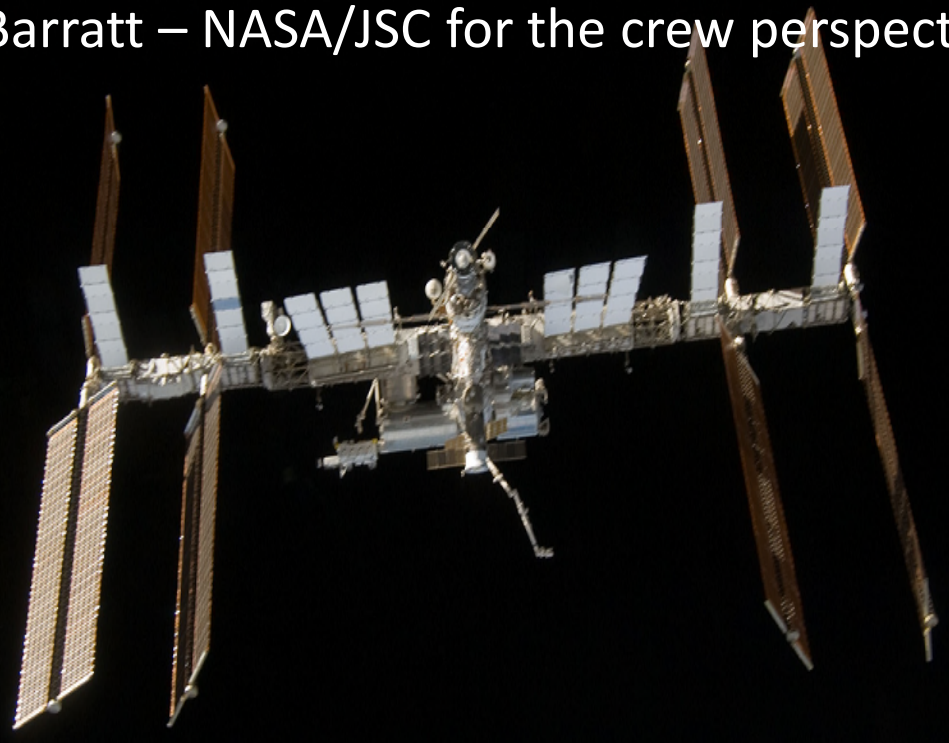
https://www.youtube.com/watch?v=EHKQIC5p8MU

Acknowledgements

- My parents

- Robert Goddard, Konstantin Tsiolkovsky and everyone who followed the dream of space exploration as an astronaut, engineer, chemist, biologist, mathematician, scientist or physician.

- Astronaut Michael Barratt – NASA/JSC for the crew perspective on artificial gravity.



- Everyone who came to listen to this presentation today

The future of space exploration is in your hands!